MPAS AND CESM

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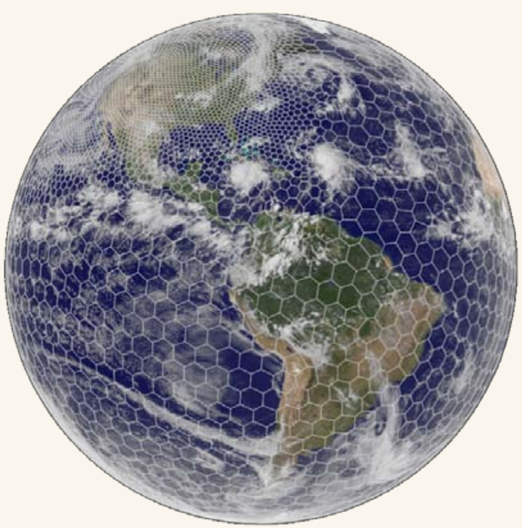
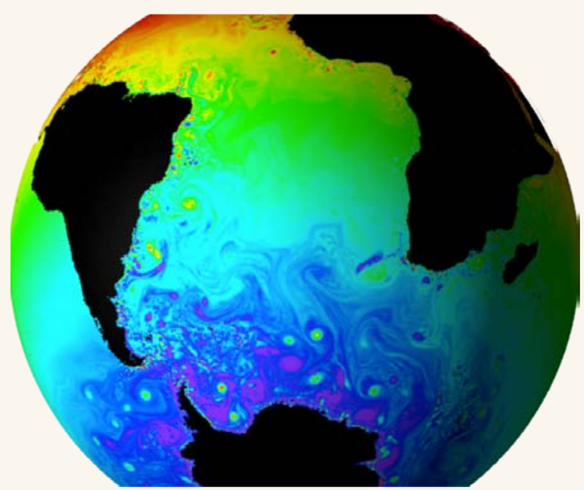
WHAT IS MPAS?

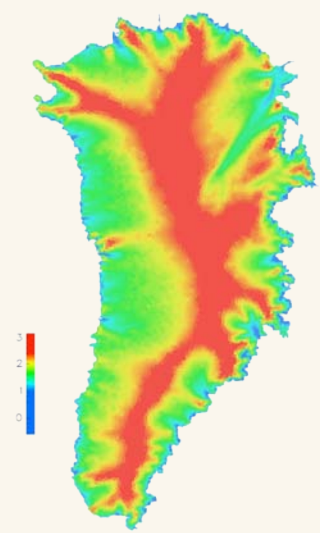
A collaboration between LANL (COSIM) and NCAR (MMM) to develop models for climate, regional climate, and NWP applications:

- MPAS-Atmosphere (NCAR)
- MPAS-Ocean (LANL)
- MPAS-Ice (LANL)
- MPAS framework, infrastructure (NCAR, LANL)

MPAS models are based on the centroidal Voronoi tessellation (CVT) with a C-grid staggering; models are conservative (total energy, mass, and potential vorticity)





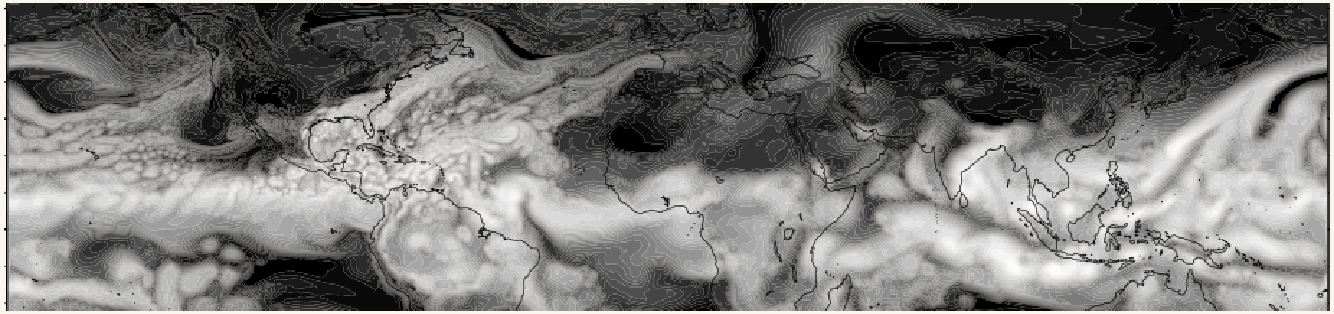


from Ringler et al. (2008)

A BRIEF HISTORY OF MPAS DEVELOPMENT

- Code development began in late 2008
  - Mesh generation, simple toy framework, shallow water model
- Fall 2009: First version of hydrostatic atmosphere model
- Summer 2010: First version of non-hydrostatic atmosphere model
- **Summer 2010: Completed work for implementation of hydrostatic model in CAM**
- Current status
  - Real bathymetry ocean simulations
  - Real-data simulations in non-hydrostatic atmosphere core
  - **Initial testing of coupled simulations (F-configuration) using hydrostatic atmosphere core in CESM**

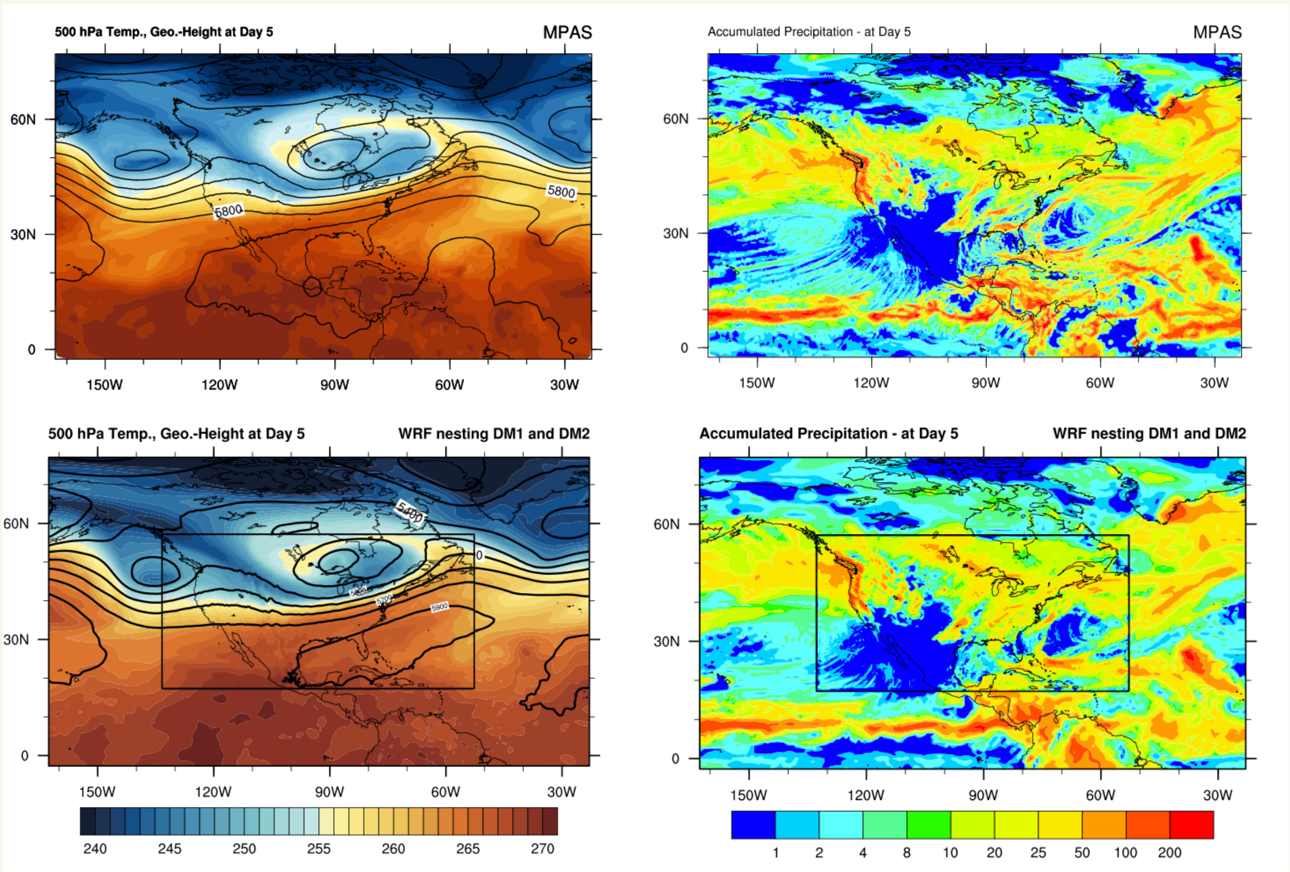
Lower-troposphere water vapor field from day 5 of an MPAS non-hydrostatic atmosphere simulation with ~160 km to ~21 km mesh refinement over North America



CURRENT STATUS OF MPAS-A (NON-HYDROSTATIC)

Testing of multi-resolution atmospheric simulations has recently begun using realistic topography, land use, ICs, etc.

- Comparisons against WRF and analyses are encouraging



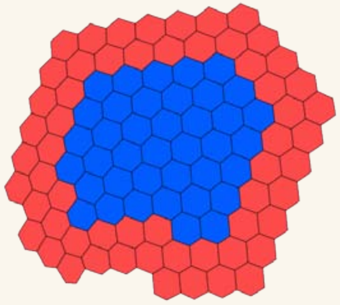
Cutout from an MPAS multi-resolution simulation (~92 km refined to ~25 km over the North American region)

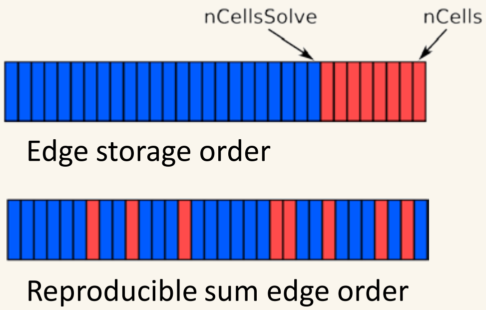
Cutout from a global WRF (90 km) simulation with a nest (30 km) over the boxed area

Figures from Fowler et al. "Cloud- and Global-Scale Simulations in MPAS and WRF," poster P.15, 12th WRF Users' Workshop.

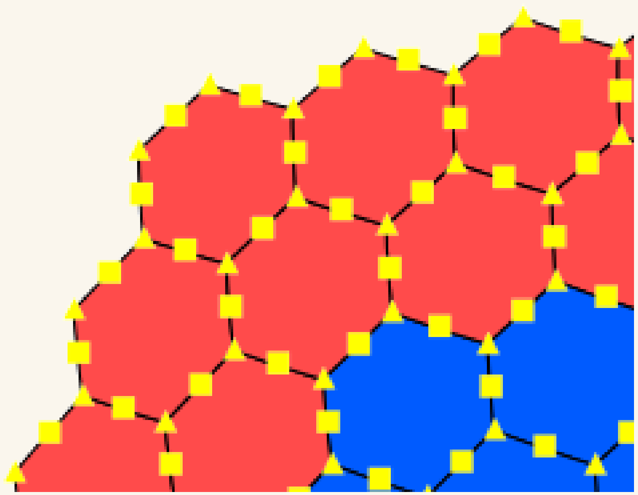
MPAS SOFTWARE STATUS AND ISSUES

- Bit-for-bit restartability (with physics in stand-alone MPAS-A)
  - Was simple to achieve
- Bit-identical results on different task counts (currently dynamics only in MPAS-A)
  - Required dealing with order-of-summation issues
  - Can be easily dealt with in ocean and hydrostatic cores, too
  - Changing to highlighted code gives ~11% performance hit on bluefire for the example loop shown below





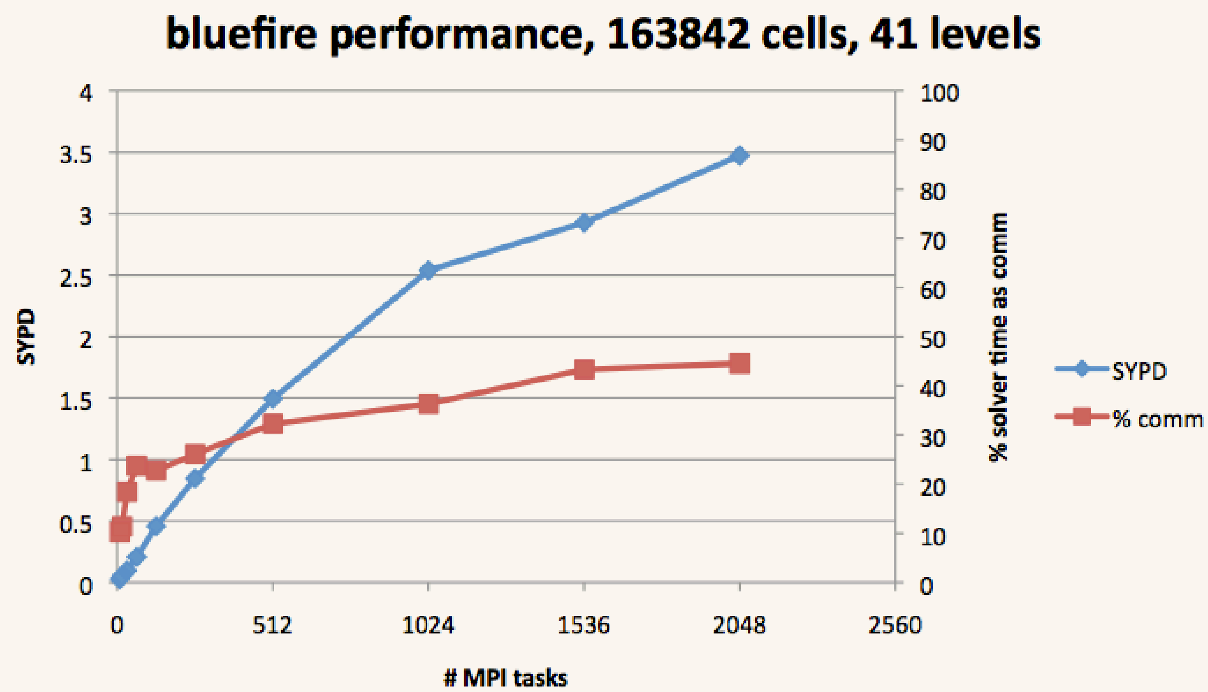

```
do iEdge = 1,grid % nEdges
do iEdge1 = 1,grid % nEdges
  iEdge = grid % edgePermutation % array(iEdge1)
  do k=1,nVertLevels
    circulation(k,verticesOnEdge(1,iEdge)) -= dcEdge(iEdge)
                                              * u(k,iEdge)
    circulation(k,verticesOnEdge(2,iEdge)) += dcEdge(iEdge)
                                              * u(k,iEdge)
  end do
end do
```



MPAS SOFTWARE STATUS AND ISSUES

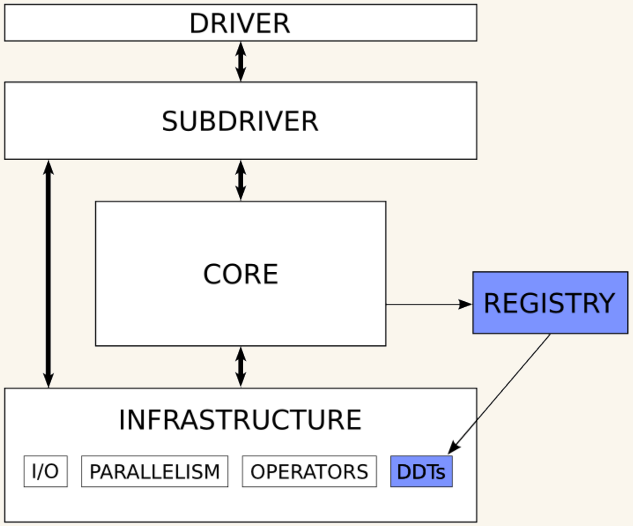
NB: We've placed no emphasis on writing fast code so far! Correctness and rapid development have been foremost.

Right: Initial performance for MPAS non-hydrostatic atmosphere core on bluefire with a ~60-km global mesh; times for dynamical solver only; SYPD assumes a 300 s time step.

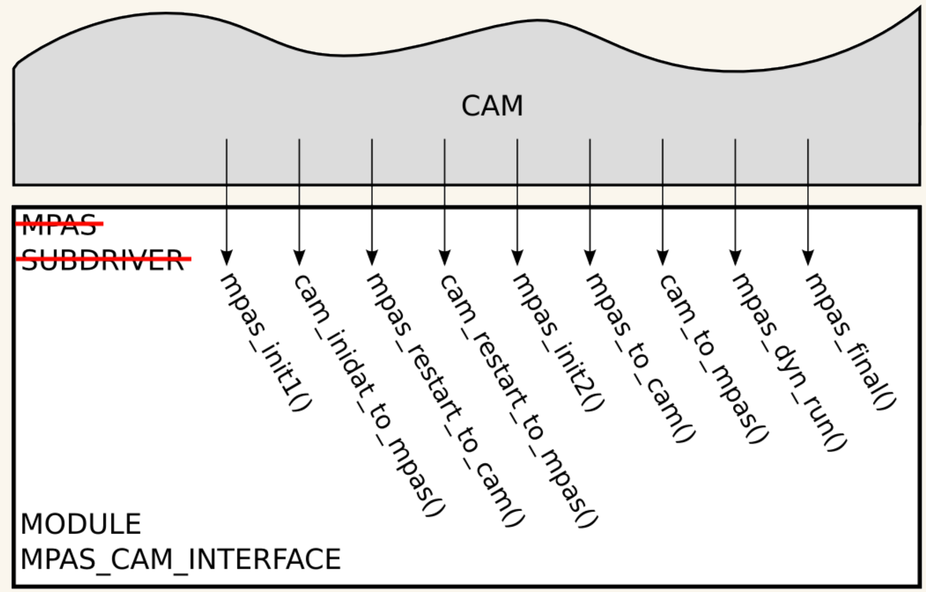


- Experience indicates that atmospheric solvers are about 2-3x slower than, e.g., CAM FV core
- What is considered good scaling on bluefire? Access to other hardware may be helpful
- My opinion: we have quite a few opportunities for improving performance and scalability in MPAS

MPAS HYDROSTATIC CORE IN CAM



Above: An idealized schematic of the MPAS software architecture



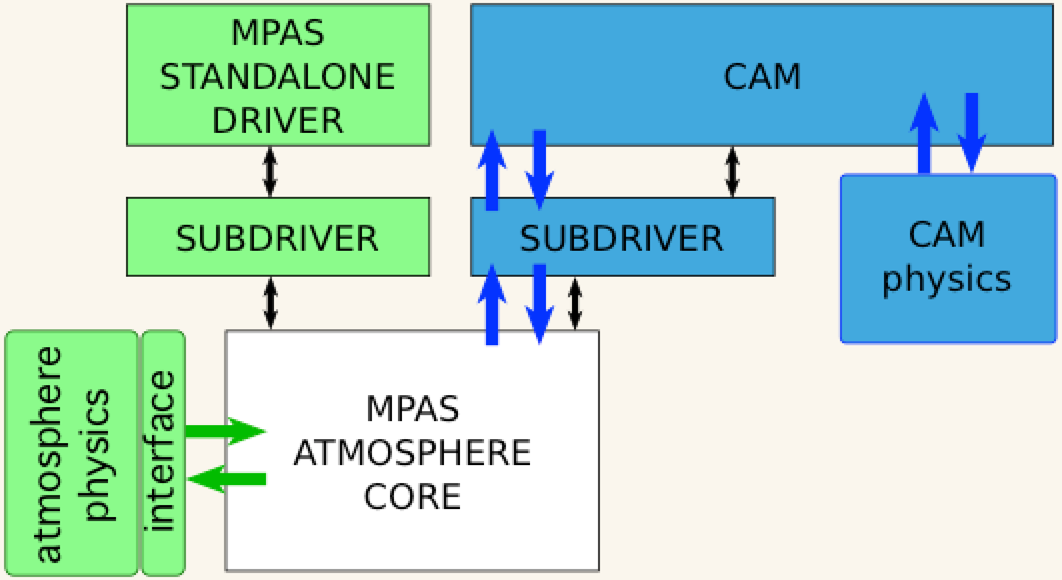
MPAS development essentially involved re-implementing the SUBDRIVER module with CAM-specific interface routines

- Some generalization to MPAS routines (e.g., optional MPI communicator argument to parallelism infrastructure init)

Import state	Export state	Control
cam_inidat_to_mpas cam_restart_to_mpas cam_to_mpas	mpas_restart_to_cam mpas_to_cam	mpas_init1 mpas_init2 mpas_dyn_run mpas_final

MPAS HAS BEEN INTEGRATED INTO CAM

- A separate branch of the MPAS code has been used for integration work so far
  - The changes required in this branch should be merged back in to the MPAS trunk



BLUE=code used when running MPAS in CAM,CESM

GREEN = code used when running stand-alone MPAS

- When running MPAS hydrostatic core within CAM, physics tendencies are stored in tendency arrays; no calls through physics interface
- When running MPAS non-hydrostatic core, physics tendencies placed in tendency arrays within calls through physics interface

MPAS HAS BEEN INTEGRATED INTO CAM

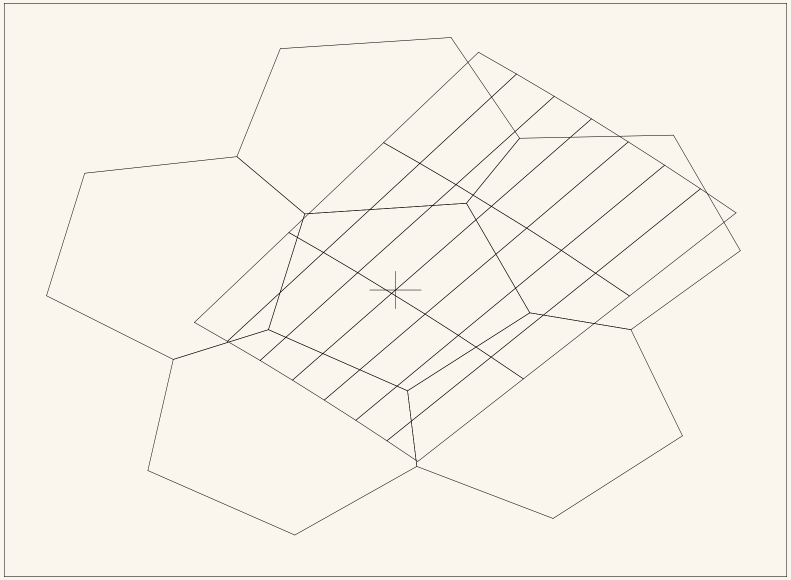
- **Integration procedure similar to that of SE (HOMME) dycore**
- **CAM calls MPAS driver and interface routines**
  - **dynamics state transferred from MPAS to CAM**
  - **physics tendencies transferred from CAM to MPAS**
- **Physics evolves on MPAS grid**
  - **physics load-balancing options supported**
- **Vertical coordinate (eta-based) uses dry rather than total pressure**
- **Code validation**
  - **dynamics validated using Jablonowski/Williamson baroclinic wave test**
  - **physics validated by comparing tendencies with FV dycore**
- **Aqua-planet validation cases carried out on quasi-uniform grids of 120km, 60km and 30km, and on 60-120km locally refined grid**

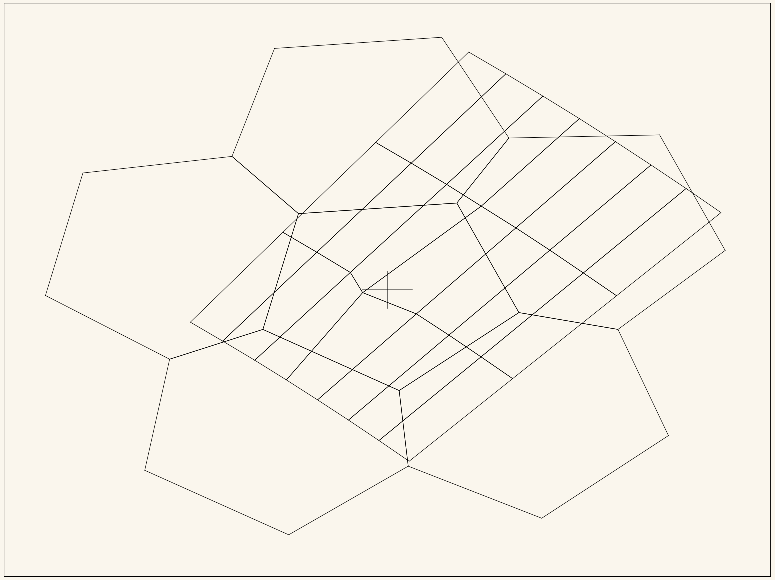
CAM/MPAS HAS BEEN INTEGRATED INTO CESM

- **This enables simulations with land (CAM/MPAS supports only aqua-planet scenarios)**
- **The only additional steps were to modify a few files in the *scripts* directory**
- **The code integration is based on cesm1_0_beta07**
- **Scrip was (initially) used to compute conservation remap files between the MPAS (1-deg; 40962 points) grid and both the land (0.9x1.25) and ocean (gx1v6) grids**
- **We carried out one-year CESM/MPAS demonstration case using the F-configuration (active land, prescribed sea-ice, data ocean)**

WE ENCOUNTERED DIFFICULTIES REMAPPING TO GX1V6 GRID

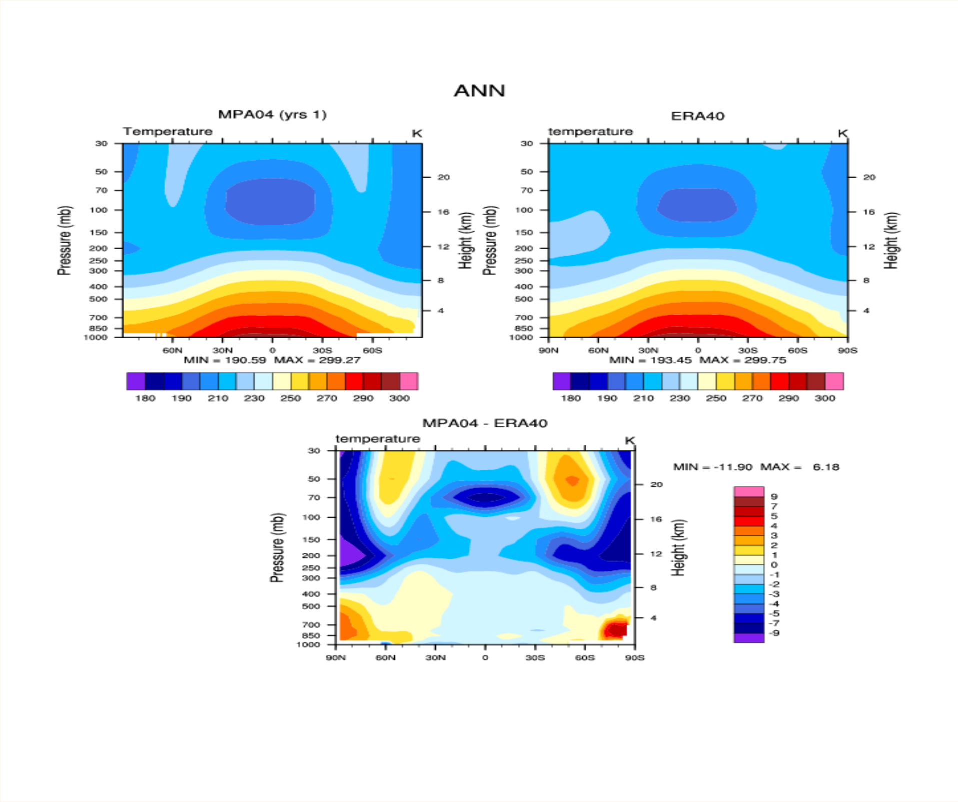
- **The ocean grid box boundary lies extremely close to north pole**
- **SCRIP has difficulty handling the polar singularity**
- **We moved a single ocean grid point towards a neighboring point to eliminate negative weights**
- **We subsequently discovered that the ESMF remapping utility does not exhibit the negative weight problem**





ACCOMPLISHED CESM/MPAS TRI-GRID DEMONSTRATION CALCULATION

- **We carried out one-year CESM/MPAS demonstration case at 1-deg resolution using the F-configuration (active land, prescribed sea-ice, data ocean)**
  - **atmosphere – 40962 points**
  - **land – 0.9x1.25**
  - **ocean – gx1v6**
- **Post-processed with AMWG diagnostics package**



CONCLUSIONS

- MPAS hydrostatic atmosphere core has been implemented within CESM; initial testing has been done
  - Issues with vertical coordinate in physics and remapping have been addressed
- The mpas_cam_coupling branch should be merged with MPAS trunk
  - Plans are in place to merge MPAS branch of CAM onto the CAM repository trunk(?)
- Begin to examine and address performance and efficiency of dynamical cores
- **Consider changes to MPAS architecture to ease the implementation of the ocean and non-hydrostatic atmosphere cores in CESM**